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METHOD FOR MANUFACTURING SINTERED PART

WHOSE SURFACE IS COATED WITH SECOND PHASE

[Hyomen O Dai Nisho De Hifukushita Shoketsu Buhin No Seizoho]

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PART WHOSE SURFACE IS COATED WITH
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Specification

1. Title of the invention

Method for Manufacturing Sintered Part Whose Surface is
Coated with Second Phase

2. Claims

1. A method for manufacturing a sintered part in which the area ratio of a second phase being exposed to the surface of a sintered body, characterized by the fact that in an ordinary method for manufacturing a powdered metallurgical product, a raw material is added mainly as a foil-shaped powder for forming a second phase to a raw material powder constituting a matrix.

2. A method for manufacturing a sintered part with antirust characteristic or corrosion resistance or changed surface hue, characterized by the fact that in an ordinary method for manufacturing a powdered metallurgical product, a second phase is composed of a material with more sufficient antirust characteristic or corrosion resistance than that of the matrix or a material with a hue different from that of the matrix; and

¹ Numbers in the margin indicate pagination in the foreign text.

a raw material for forming the second phase is added mainly as a foil-shaped powder is added.

3. The method for manufacturing a sintered part with high antirust characteristic or corrosion resistance of Claim 2, characterized by the fact that the matrix of the member is an iron or an alloy mainly composed of an iron; the second phase is composed of a copper or copper alloy or stainless steel; and the amount of foil-shaped powder being added is 10-50%.

4. The method for manufacturing a sintered part with a changed surface hue of Claim 2, characterized by the fact that the matrix of the member is an iron or an alloy mainly composed of an iron; the second phase is composed of a copper or copper alloy or stainless steel; and the amount of foil-shaped powder being added is 1-17%.

5. The method for manufacturing a sintered part of Claim 1, characterized by the fact that the second phase of the member is composed of a material with good sliding characteristic than that of the matrix; the raw material for forming the second phase is added mainly as a foil-shaped powder; the amount of foil-shaped powder being added is 0.3-3.0 times of the lower limit value that the second phase macroscopically completely coats the surface of the sintered body; and the usage of the resin is a bearing containing an oil.

6. The method for manufacturing a sintered part of Claim 1, characterized by the fact that the matrix of the member is an iron or an alloy mainly composed of an iron; the second phase is composed of a copper or copper alloy composed of copper; the amount of foil-shaped powder being added is 5-50%; and the usage of the resin is a bearing containing an oil.

3. Detailed explanation of the invention

In general, atomized powder, reduced powder, electrolytic powder, and reduced [illegible] powder with good flowability and moldability are used as a raw material powder for powder metallurgy, and metal powders for pigments/2 such as paints are work-hardened foil-shaped powders, have both poor flowability and moldability, and exhibit an abnormal expansion when sintering, they cannot be used for powder metallurgy.

However, in case a small amount of foil-shaped powder for a pigment is mixed with the above-mentioned raw material powder for powder metallurgy, the hue of the surface of the mixed powder and the pressed powder strongly exhibits the hue of the foil-shaped powder added, which is an interesting property. This phenomenon has already been experienced, however this phenomenon has not been elucidated.

These inventors first elucidated the above-mentioned phenomenon and found out that if a foil-shaped powder was added and mixed into a raw material powder for powder metallurgy, the foil-shaped powder was easily arranged in a layer shape on the surface of the mixed powder and the pressed powder. Next, the elucidation was further advanced, and a method for calculating the amount of addition required for completely coating the surface of the mixed powder and the pressed powder was found out. Also, in the addition of the foil-shaped powder, if its amount is 50% or less, it is experimentally confirmed that no particular problem is caused in terms of production, and from this fact, sintered parts to which the characteristics of a coating material are added by coating the surface with a foil-shaped powder can be produced.

The effects of the present invention is explained using a sintered part in which the matrix is an iron system and the coating material is a copper alloy as an example. If the fact that copper is more excellent than iron in the antirust characteristic and the corrosion resistance is utilized, especially in case high mechanical strength, etc., are required, the above-mentioned two properties as drawbacks of the iron system alloys can be raised up to the level of the copper alloys. Also, if the difference in the hue between both

materials is utilized, an iron system sintered part whose surface is bronze color, etc., can be easily manufactured, and the product value of its appearance can be raised. Also, in processes having a high chance of handling products with a similar shape, if one part is colored to the degree that it can be discriminated, the generation of an inferiority due to the misrecognition can be prevented, so that the control is easy. Thus, its effects are high. Also, if the excellence in the sliding characteristic of the copper alloy is utilized, a bearing containing an oil having a high load resistance, in which [illegible] is improved to the degree of the copper alloy, can be manufactured by coating the sliding surface of the iron system sintered bearing containing an oil with the copper alloy.

As mentioned above, there are many usages to which this technical method can be effectively applied, and if the matrix material and the coating material are selected in accordance with its purposes, this method can be applied in a wider range.

First, in case the foil-shaped powder is not added, the phenomenon in which it is easily arranged on the surface of the mixed powder and the pressed powder is explained.

Hereinafter, in this specification, the raw material powder for a pigment is called a foil-shaped powder, the atomized powder, reduced powder, electrolytic powder, and reduced

[illegible] powder are called ordinary powders, and the raw material particles for forming the matrix are called matrix particles.

First, the case where the raw material powder ordinarily composed of a powder element is filled in a cavity of a mold is considered. Since the gravity is exerted downward on each particle of the filled powder, the energetically most stable state is the case where the volume of the powder is a minimum state, that is, each particle is the most closely packed and filled state. This fact shows that the powder has an essential property in which the powder always tends to be in the most closely packed and filled state.

For simplicity of interpretation, if it is assumed that each particle of the powder is usually a sphere with the same radius r and the arrangement is in the most closely packed and filled state, the cross section of the filled powder in which the distance from the mold surface is r is formed as shown in Figure 1. In the figure, the circle shown in Figure 1 is a particle in interest and is included in six adjacent particles shown by 11-16. 3 is a space part existing between the particles. If a pressure molding is carried out, these particles are deformed until the space part is lost, and a shape as shown by a dotted

line in the figure, that is, a regular hexagon is formed if the influence in the pressurizing direction is ignored.

Next, it is assumed that the powder for forming a second phase is usually added in a powder shape and the particle diameter has the same r as that of the matrix powder. In this case, the arrangement is in the same most closely packed and filled state as that of the element, and as its schematic diagram, Figure 1 can be shared. Here, 1 is a particle of the second phase, and 11-16 are particles constituting the matrix. If the surface is constituted by a unit cell consisting of these seven particles, the area ratio of the second phase in the surface layer of the filled powder is $1/7$, that is, 14.3%. Since this ratio is maintained in any place in the mixed powder, the number ratio, that is, the volume ratio of the second phase in the powder is 14.3% which is the same as the area ratio of the surface layer. Also, if the amount of second-phase particles and matrix particles being deformed during molding is approximated to the same, the structure of the pressed powder is in a state shown by a dotted line in the above-mentioned same figure, and its area ratio is also approximated to the same value $1/3$ during filling, that is, the same value as the volume ratio.

Next, the case where the second phase is added as a foil-shaped powder is considered. In the foil-shaped powder for a pigment on the market, since the ratio of the diameter $2a$ and the thickness is about 20-50:1, this thickness is ignored. In this case, similarly to the above-mentioned case, the case where the matrix particles in the mixed powder is in the most closely packed and filled state is the most stable state. However, if $2a \gg r$, the arrangement state of the matrix particles is largely disturbed by the distribution of the foil-shaped particles, and the most closely packed arrangement may not be able to be obtained.

On the contrary, if $2a \ll r$, the matrix particles have the arrangement shown in Figure 1, and the foil-shaped powder of the second phase is supposed to be positioned in its cavity part. Therefore, in this case, the foil-shaped powder can be added without increasing the volume of the powder. However, in order to completely include the matrix particles, it is necessary to add the foil-shaped powder of the volume or more of the space part, and the coating effect of the surface is small, compared with the effect that will be mentioned later.

If $2a \approx r$, since the foil-shaped particles cannot be included in the space part in terms of size, they are supposed to be positioned between the matrix particles. If their size

and number meet the optimum conditions, the two-dimensional model of the arrangement is in a state shown in Figure 2, and each matrix particle is in a state in which its periphery is completely enclosed with the foil-shaped powder. In the figure, 4 shows the cross section of the foil-shaped powder.

In this state, if a pressure molding is carried out, the matrix particles 1 and 11-16 and the foil-shaped particles 4 are deformed, and as shown by 1', 11'-16', and 4' of Figure 3, the foil-shaped particles are supposed to exist in [illegible] shape at the boundary part between the matrix particles.

Here, Figure 2 shows the arrangement of the particles perpendicular to the surface of the filled powder, and if the surface layer of the powder is the matrix particles 14, 1, and 11, the matrix particles 15 and 16 and foil-shaped particles 41 are excluded from the figure in the arrangement of the particles in the vicinity of the surface layer. At that time, foil-shaped particles shown by 42 and 43 exist respectively between the matrix particles 1, 16 and 1, 15, and one foil-shaped particle is shared with two matrix particles. Therefore, the probability that the foil-shaped particles 42 and 43 belong to the filled powder side is $1/2$ in both of them.

In order to set this probability to 1, that is, to completely coat the surface of the powder with the foil-shaped

powder, the number of foil-shaped particles existing between the matrix particles may be two. This arrangement state is shown in Figure 4. In the figure, 44 shows the above-mentioned two foil-shaped particles, 4 shows a foil-shaped particles of one layer of the powder surface, and 6 shows the surface of the powder.

In the state of Figure 4, if a pressure molding is carried out, a structure shown in Figure 5 is shown. The left side of the figure shows a state in which a hole 3' exists in the pressed powder, and the right half of a model diagram showing a state in which the hole is reduced. In the figure, 44' shows two deformed foil-shaped particles existing between the deformed matrix particles, and 45' shows one deformed foil-shaped particle existing on the surface layer.

The above facts are summarized as follows. In other words, if the raw material for forming the second phase is added as a foil-shaped powder to the raw material powder for forming a matrix, there is an essential property in which the foil-shaped powder is arranged in a layer shape on the surface of the mixed powder and the pressed powder. The coating effect of the surface based on such a property is maximum when $2a \approx r$, followed by $2a \ll r$, and the property is little shown when $2a \gg r$ which may be almost the same as the case where a normal powder is added.

The average particle diameter of the raw material powder being used in the production is usually about 74μ (200 mesh), whereas the average particle diameter of the foil-shaped powder for a pigment is about $10-40 \mu$. Thus, the maximum condition of the above-mentioned coating effect is almost met.

From this fact, it is understood that if a foil-shaped powder for a pigment on the market is added and mixed with a raw material being ordinarily used for powder metallurgy, the foil-shaped powder almost has an optimum condition for an easy arrangement in a layer shape on the mixed powder and the pressed powder.

Next, a minimum amount of foil-shaped powder required to completely coat the surface layer of the powder and the pressed powder with the foil-shaped powder and to be the second phase is estimated.

For this purpose, the condition shown in Figure 4, that is, a monolayer polyhedron externally contacts with one ordinary particle may be formed by the foil-shaped particles. For this state, it is convenient to compare the surface area of both of them. In other words, if the foil-shaped powder with a specific surface A_{f0} is added to the matrix powder with a specific surface A_n and the composition of the former is assumed as x , the surface S_{f0} of the foil-shaped powder in the mixed powder

with a weight of W in contact with $/4$ the matrix powder and the surface area S_m of the matrix powder are shown by the following expressions.

$$S_{f0} = A_{f0} \cdot x \cdot W/2$$

$$S_m = A_m \cdot (1 - x) \cdot W$$

In a foil-shaped powder for a pigment on the market, the coating force A_f is shown as its characteristic value. This value shows the area occupied by the case where 1 g foil-shaped particles are arranged to the degree that they contact with each other as approximately shown in Figure 1, and there is the following relationship between the coating force and the specific surface.

$$k_1 \cdot A_f = A_{f0}/2$$

Where, $k_1 \approx 0.85$.

Since the ratio of the surface area of the externally contacting polyhedron to the surface area of the spherical particles is k_2 and both powders have a wide particle size distribution and cannot be coated in the above-mentioned ideal state, if the coating efficiency k_3 is introduced, the area S_f of the matrix powder being coated with the foil-shaped powder is shown by the following expression. In other words,

$$S_f = S_{f0} \cdot k_3/k_2$$

$$= A_f \cdot x \cdot W \cdot k_0$$

Where, $k_0 = k_1 \cdot k_3/k_2$.

If the low limit value of the composition for a macroscopically complete coating is x_0 , since $S_f = S_m$ at x_0 ,

$$x_0 = A_m / (A_m + k_0 \cdot A_f)$$

(1)

$$k_0 = A_m / (1 - x_0) / A_f \cdot x_0$$

(2)

k_0 is attained as follows. In other words, the composition x_0 at which the entire surface area is macroscopically coated with the second phase is attained from actual values and calculated from known A_m and A_f by the expression (2). Also, if k_0 is discriminated, x_0 can be attained by the equation (1).

As seen from the above-mentioned explanation, since k_1 and k_2 are fixed numbers close to 1, $k_0 \approx k_3$, and $1/k_0$ is an average number of the layer of the foil-shaped particles that enclose each matrix particle at an amount x_0 of foil-shaped powder being added. Also, it is multiplied by the thickness of the foil-shaped powder, the average value of the thickness of the coating layer of the surface can be attained.

Next, using examples of an iron system sintered material to which a foil-shaped copper powder for a pigment is added, the contents of this technical method are explained in detail.

Application example 1

As a raw material powder in this example, a reduced iron powder as an ordinary powder for a matrix, a copper powder for a pigment as a foil-shaped powder for forming a second phase, and an electrolytic copper powder as an ordinary powder for comparison were used. The characteristic values of these powders are shown in Table 1. Also, the coating force of the foil-shaped copper powder is a catalogue value, and the specific surface area of the iron powder is a value calculated from [illegible] value, assuming the particle shape as a sphere and the particle diameter of 325 mesh or smaller as 0.03 mm.

TABLE 1

特 性 項 目		粉 末 の 種 類		
		鉄 粉	箔状銅粉	電解銅粉
粒 度	+ 100メッシュ	1.0	—	—
	+ 145 "	27.3	—	10.2
分 布	+ 200 "	31.7	1.5	30.2
	+ 250 "	15.0	8.0	18.0
%	+ 325 "	12.2	14.8	17.8
	— 325 "	12.8	75.7	23.8
比表面積 (cm ² /g)		104	—	—
被覆力 (cm ² /g)		—	1500	—

1. Characteristic item
2. Kind of powder
3. Particle distribution %
4. Specific surface (cm²/g)
- Coating force (cm²/g)
5. Mesh
6. Iron powder

7. Foil-shaped copper powder
8. Electrolytic copper powder

The above-mentioned two kinds of copper powders of 5, 15, and 30% were added and mixed to the above-mentioned iron powder, so that six kinds of mixed powders in total were prepared. Then, they were subjected to a pressure molding to obtain a pressed powder density of 6.70 g/cm^3 , and rectangular parallelepiped pressed powders with a length of 5, 10, and 20 mm of three sides was prepared. These pressed powders were sintered at 900°C for 1 h in a decomposed ammonia atmosphere, and the area ratios of the coating parts of the copper of the surfaces was attained from photomicrographs of the surfaces of the sintered bodies.

The surface area $A_f \cdot x$ of the foil-shaped powder part in the mixed powder used in the preparation of each sample, the surface area $A_m \cdot (1 - x)$ of the matrix powder part, and the actual value of the coating area ratio of the copper of the sintered body surface were shown in Table 2. When the composition at which the coating area ratio was 1, that is, x_0 was attained from curve 7 of Figure 6 showing the relationship between the coating area ratio and the composition, it was 17%,

and when k_0 was attained from the expression (2), it was $1/3$.

Also, the composition x of the foil-shaped copper powder was described as x/x_0 .

TABLE 2

特 性 项 目		试 样 名 称		
		1	2	3
配合组成	铁 粉 %	85	85	70
	铜 箔 %	5	15	30
$A_{Fe} \cdot (1-x)$ cal/g		88.8	88.4	72.8
$A_{Cu} \cdot x$ cal/g		75	225	450
$A_{Fe} \cdot x / A_{Fe} \cdot (1-x)$		0.76	2.55	8.18
被覆面积比		0.4	0.9	1.0
x/x_0		0.29	0.88	1.76

1. Characteristic item
2. Name of sample
3. Mixture composition iron powder %
 copper foil %
4. Coating area ratio

Interestingly, the value of x/x_0 almost agrees with the actual value $1/5$ of the coating area ratio and can be used as its approximate value. Also, as a comparative material, the coating area ratio with a sintered body in which the foil-shaped powder is substituted by the same amount of electrolytic copper powder is shown in curve 8 of figure 6. From the results of the

figure, it could be confirmed that this technical method had a large coating effect.

$x_0 = 17\%$ and $k_0 = 1/3$ obtained in this application example show the following. In other words, if the foil-shaped powder is added at 17%, the entire area of the surface is macroscopically coated with copper. In this case, foil-shaped particles of three layers are averagely superposed in the powder surface.

Also, as shown in Figure 5, under the ideal condition ($k_0 = 1$) in which the enclosure is carried out by the foil-shaped powder of one layer, the above-mentioned amount being added was 5.7% from the expression (1).

Also, the phenomenon experienced in this application example is as follows. First, as the measured values of the coating area ratios of the pressed powders, the same values as that of each sintered body were obtained in a measurement error range. Also, though the coating area ratio of the surface of the mixed powder was not measured, judging from the hue, it was estimated in the same manner as that of the pressed bodies and the sintered bodies using them. Also, it was confirmed that the hue of the cross sections of these samples was much deficient in the copper color, compared with the surface.

The following three items should be noted when this technical method is applied.

Its first item is a sintering condition, and the condition in which the surface layer coated during molding is largely reduced by diffusion, etc., during sintering is required to be avoided. In the above-mentioned application example, when the sintering temperature was the melting point or higher of the copper, the copper of the surface area was melted and introduced into holes existing in the sintered body, so that the coating effect was lost.

Secondly, as the specific surface of the matrix powder, a value calculated from the particle size distribution is preferably used as shown in the application example. For example, for a reduced powder, the specific surface attained by a gas adsorption method is a value of several times of the above-mentioned calculated value. It is due to the inclusion of the surface area of a large amount of hole parts existing in the powder, etc.

Since the value required for applying this technical method is the surface area of the outer peripheral part of the particles, even if the error due to the approximation as a spherical shape is considered, the above-mentioned calculated value shows a value closer to this purpose.

Thirdly, if an element being evaporated and flown during sintering is included in the foil-shaped powder, its flight prevention measure is required. As an example, in case a copper-zinc material is used as the foil-shaped powder, zinc is vaporized and flown during sintering, and the surface of the sintered body exhibits a copper color. However, if the pressed powder was sintered in a mixed powder of copper-zinc alloy powder and alumina, the dezincification of the surface layer could be easily prevented.

If the above-mentioned points are considered, a sintered product whose surface is coated with the second phase can be manufactured for a wide range of materials.

The above-mentioned k_0 or x_0 is required to be attained from actual values or by calculating from them for each combination of the matrix powder and the raw material powder for the second phase being used. However, if the matrix and the second phase are respectively limited to an iron system and a copper system with a high usage frequency, the raw material powder is restricted in terms of productivity, etc., by itself, and the characteristic value and k_0 of the raw material powder in the expressions (1) and (2) are almost the same values. In other words, $A_f \text{ @ } 1,500 \text{ cm}^2/\text{g}$, $A_m \text{ @ } 100 \text{ cm}^2/\text{g}$, and $k_0 \text{ @ } 1/3$, and even

if x_0 @ 17% calculated from them is a fixed value, little practical problem is caused.

Also, the amount of foil-shaped powder being added is required to be determined in accordance with its purpose. As have already been mentioned above, since x/x_0 shows a value approximated to the coating area ratio of the second phase, the amount being added is shown by x/x_0 for convenience.

In the case where the matrix is iron and the second phase is copper shown in Application Example 1, if coloring is carried to the degree that it can be simply discriminated, like the case for the purpose of identification of imitations, $x/x_0 = 0.06$, that is, 1.0% is sufficient.

In case the hue is required to be set by several stages, in addition to the above-mentioned values, the amount being added such as $x/x_0 = 0.2$ (3.4%) and 0.4 (6.8%) is changed, or the second phase is further a material with a different hue, so that the purpose can be achieved. The upper limit value of the amount being added for this purpose is a composition in which the entire area of the surface is coated, that is, $x/x_0 = 1$ (17%). If the matrix is an iron system, a preferable material as the second phase is copper and copper system alloys such as copper-tin system, copper-zinc system, and copper-tin/6 -zinc system having a hue considerably different from that of iron.

Next, in case the antirust characteristic is required, the matrix is not necessarily completely coated with the second phase. Even at $x/x_0 = 0.6$ (the combination of Application Example 1, 10%), the antirust characteristic is considerably improved, and little practical trouble is caused. However, for the purpose of the corrosion resistance in which even the existence of pinholes becomes a problem, even if a macroscopically complete coating is carried out at $x/x_0 = 1$, since a microscopic complete coating can be little expected, the amount being added is required to be increased as needed until x/x_0 reaches about 2 (34%) or 3 (51%).

Therefore, in an iron system sintered material for antirust and corrosion resistance having a copper or copper system alloy as the second phase, the lower limit value of a foil-shaped powder being added was 10%, and the upper limit value was 50%.

The material for forming the second phase suitable for this purpose is appropriately a copper system alloy and a stainless steel of a monolayer such as copper-tin, copper-zinc, copper-tin-zinc, and copper-nickel in addition to copper. In the stainless steel, the amount being added also can achieve the purpose in the above-mentioned range.

Next, in addition to the above-mentioned usages, the sintered bearing containing an oil in which a large effect is

expected by the application of the present invention is explained.

In general, the bearing performances are largely divided into the following three items. In other words, they are load resistance, wear resistance, and [illegible]. Since the load resistance means the pressure resistance under operation conditions and as the wear resistance, the wear under ordinary conditions is due to the mechanical fracture, a large mechanical strength is desired as a bearing material in both items. However, in [illegible], the softness being deformed in accordance with the other shaft is required, and the condition is contradictory to the above-mentioned two items.

The sintered bearing containing an oil is largely divided into two systems of a copper system and an iron system. In the bearing characteristics, the copper system is excellent in [illegible], and the iron system is excellent in the load resistance. However, the maximum merit of the latter is a low cost based on an inexpensive raw material cost, and the iron system is broadly used except for the usage that requires [illegible] in particular. Also, bearings to which the merits of both the iron system and the copper system are provided by adding a large amount of copper system material such as the addition of 25% copper at maximum and the addition of up to 85%

copper-zinc alloy are developed. However, in manufacturing them, a large increase of the raw material cost cannot be avoided.

The major factors for determining [illegible] of the bearing containing an oil composed of two phases of an iron system and a copper system are the material of a soft phase in the sliding surface and its amount. If an iron system sintered bearing containing an oil in which the surface layer, that is, the sliding surface is coated with a small amount of copper system soft phase is manufactured by applying this technical method, a bearing with about the same characteristics as those of a copper system bearing can be manufactured with a slight increase of the raw material cost.

Also, in the conventional method, an iron system bearing in which the surface is completely coated with a copper system material, which has not been able to be realized, can be manufactured, and a further improvement of the performances is expected, compared with the above-mentioned ones.

As an example in which the amount being added can be reduced, an iron system sintered material in which an ordinary powder with a composition of Cu-30% Zn is added at 40% to a second phase is explained. The copper system phase in the above-mentioned composition material is 38 vol%, and the area

ratio in the alloy powder addition having an ordinary shape is 0.38. The required amount of foil-shaped powder being the area ratio is about 65% if A_m and A_f shown in Application Example 1 are used, and the amount being added can be reduced to about $1/6$.

The limit amount being added at which the bearing characteristics are distinctly improved by adding a foil-shaped copper system metal powder to an iron system sintered bearing material containing an oil was attained. This result depends on the sliding conditions. When the PV value was 300 ($\text{kg}\cdot\text{m}/\text{cm}^2\cdot\text{min}$), $x/x_0 = 0.3$ (5.0%), and when the PV value is as high as 1,200, $x/x_0 = 0.5$.

Also, even if the amount being added was $x/x_0 \approx 1$ under the former condition and the amount being added is $x/x_0 = 3$ (50%) or more under the latter condition, a further improvement of the sliding characteristic was not recognized, and the decrease of the mechanical strength was distinct. Thus, the lower limit was set to 5%, and the upper limit was set to 50%. Also, the limit PV value of the bearing of this example in which no copper was added was 1,500.

Also, in case the matrix was an iron system, the material suitable for the usage as a second phase is copper alloys such as copper-tin, copper-lead, copper-tin-lead, and copper-zinc

being broadly used as bearing materials in addition to the above-mentioned copper. Also, if a slight amount of solid lubricant such as graphite and molybdenum disulfide is added to them, needless to say, the bearing characteristics are further improved, and the addition of them is also included in the alloy mainly composed of iron in the present invention.

Hereto, the sintered bearing containing an oil in which the matrix is/7 an iron system and the second phase is a copper system has been explained, however there is no reason why the combination of two kinds of materials is limited to the above-mentioned system. In the combination in which the matrix is a material with a high mechanical strength and the second phase is a material with a large flexibility to the material of a shaft, if the second phase is added by a foil-shaped powder, needless to say, an effect similar to the above-mentioned effect is shown, and the amount being added is also similarly $x/x_0 = 0.3-3$.

The foil-shaped powder suitable for this technical method, as seen from the above-mentioned explanation, the amount being added can be reduced with the increase of the coating force, so that the effects of this technical method can be further raised. The lower limit of the coating force of products on the market is usually $1,000 \text{ cm}^2/\text{g}$, however even if a powder showing a

coating force of $500 \text{ cm}^2/\text{g}$ is used, a distinctly large coating effect was shown, compared with an ordinary powder addition.

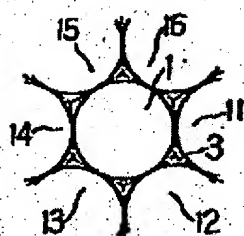
Also, any particle size, as have already been mentioned, has been employed without a problem as long as it is a raw material powder of 100 mesh or smaller on the market. From these facts, the foil-shaped powder in the present invention was limited to a powder with a coating force of $500 \text{ cm}^2/\text{g}$ or more and a particle size of 100 mesh or smaller. Also, the expression of the foil-shaped powder as a main component means that a layer-shaped alloy phase is formed by adding a second phase as a pure metal or an alloy foil-shaped powder and diffusing it during sintering, so that the second phase is obtained. As an example, even if a foil-shaped copper powder and an ordinary powder of its 10% copper are added, the surface of the sintered body is almost similar to the case where a foil-shaped alloy powder of Cu-10% Sn is added. However, since the coating effect of the surface is considerably larger in the foil-shaped powder, it is preferable to use the foil-shaped powder with a second phase composition to increase the effect to the maximum. As mentioned above, in case only the copper powder or part of a copper-tin alloy is added as an ordinary powder, the effect is reduced as much as the amount given as an ordinary powder. However, if the amount of ordinary powder being added is considerably small to

the amount of foil-shaped powder, such an effect is not substantially changed.

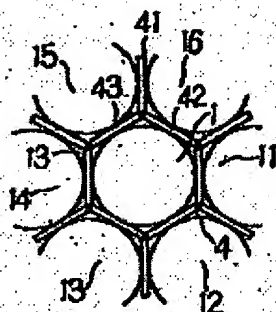
4. Brief description of the figures

Figure 1 shows an arrangement state of particles in the case where a raw material powder is in the most closely packed and filled state. Figure 2 shows an arrangement state of raw material particles in the case where a foil-shaped powder is added. Figure 3 is a schematic diagram showing the structure after molding a foil-shaped powder. Figures 4 and 5 are respectively schematic diagrams showing the particle arrangement and the structure in the vicinity of the surface layer in Figures 2 and 3. Figure 6 is a graph showing the experimental results for the coating effect when the foil-shaped powder added by the present invention.

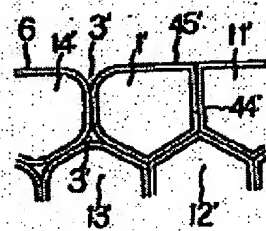
第1圖



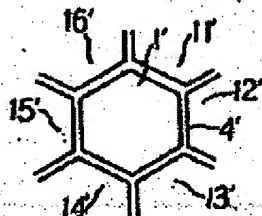
第2圖



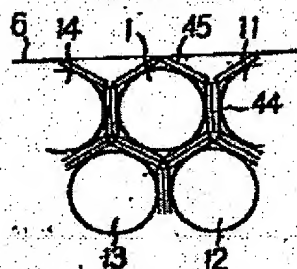
第5圖



第3圖



第4圖



第6圖

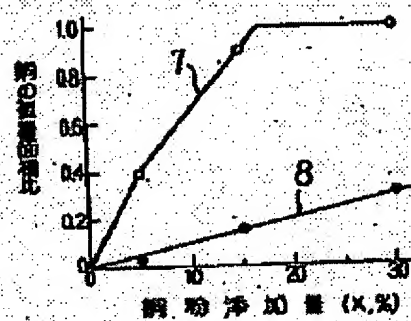


Figure 6:

1. Coating area ratio of copper
2. Amount of copper powder added (x%)